3.4 Aloft Meteorological Measurements

The Routine Network in southern California includes meteorological resources aloft such as radar wind profilers and radio acoustic sounding systems – SCAQMD stations – Los Angeles and Ontario airports; the Ventura CAPCD station – Simi Valley; the San Diego CAPCD stations – Point Loma and Valley Center. During SCOS97-NARSTO additional units were added – ARB stations – the El Monte Airport and the Norton Air Force Base; the NOAA [William Neff] stations – Alpine Meteorological, Goleta, Los Alamitos, Port Hueneme, Carlsbad, Palmdale, San Clemente Island Meteorological, Santa Catalina Island Meteorological, Tustin, University of Southern California Meteorological, and the Van Nuys airport; the NOAA [M.J. Post] stations – Brown Field and El Centro; the Radian-STI stations – Barstow Meteorological, Riverside H.G. Mills Water District, Temecula East Municipal Water District, Thermal Airport, and Hesperia Oak Hills Center; the U.S. Air Force stations – three sites at Vandenberg Air Force Base. SCOS97-NARSTO sound detection and ranging instruments included the NOAA [William Neff] stations – Los Alamitos, Azusa Meteorological, Santa Clarita, and Vandenberg Air Force Base; San Diego CAPCD station – Warner Springs Meteorological; and U.S. Marines stations – two sites at 29 Palms. The RWP-RASS and sodar networks are listed in Tables 1 and 2. As it did before the study, NOAA still operates stations at Goleta and San Clemente Island.

The thirteen site rawinsonde network included the ARB station – Bakersfield Meteorological; the National Weather Service (NWS) station – Miramar; the military bases – 29 Palms, Edwards Air Force Base, China Lake, Tustin [El Toro operations moved to Tustin], San Nicolas, Point Mugu, North Island Naval Air Station [launch station moved to Imperial Beach], and Vandenberg Air Force Base, and the CE-CERT stations at UCLA, UC Riverside CE-CERT Facility, and Pomona. Meteorological parameters were available from seven ozonesonde site network from the CE-CERT stations – Anaheim, California State University at Northridge, Valley Center, Pomona, UC CE-CERT Facility, University of Southern California Hancock Building; and from the U.S. Navy station at Point Mugu. Tables 3 and 4 list the SCOS97-NARSTO sonde network. Currently, military and NWS still stations continue their rawinsonde operations as before SCOS97-NARSTO.

Before incorporating such a wealth of meteorological resources aloft, as the SCOS97-NARSTO provides, into modeling and data analysis, it may be found that data from some platforms at some locations would require further scrutiny. This section discusses collocated rawinsondes and profilers available to plan data comparisons. AeroVironment group's report already discusses methods, issues, and results of the comparison of sodar and profiler data. Both these types of data comparison are critical in preparing inputs for meteorological models; they are also critical for the kind of iterative quality control necessary to investigate new meteorological phenomena and to validate conceptual models of the southern California regional meteorology.

Rawinsonde and radar wind profiler-radio acoustic sounding (RASS) systems data can only be reasonably compared within the ground-based systems' radius of influence (Douglas et. al, 1997). Depending on the terrain of the profiler location and with the help of meteorological modeling resources, these radii can be determined. Data from elements of the rawinsonde network, close to but not exactly collocated with the profiler and within this radius, may then provide data for this type of comparison.

However, certain fundamental issues intrinsic to this type of comparison must be noted. Profiler-RASS systems produce statistical data. This means that for each elevation bin, each hourly value is a representative (e.g., mean or median) of at least five to ten values; these instruments can produce data at very small fractions of an hour. It may be more important to see how the rawinsonde data fit within the envelope of these values than how well the average profiler-RASS data agree with the instantaneous rawinsonde data (Figure 1-2b SAI report)(Douglas et. al, 1997).

Each platform also has uncertainties related to the different methods of measurement. For example, RASS uses the speed of sound through the air to measure temperature while rawinsonde thermistors record changes in the electrical resistance of their active element with respect to ambient temperature. RWP records a single vertical profile for wind data, while a rawinsonde reports wind data while it travels ten to thirty kilometers horizontally as it moves aloft. Differences between temperature data collected by nearly collocated rawinsonde, aircraft, and RWP-RASS instruments, available for August 1 and 4, 1992, at Hesperia (Figure 1-10a SAI report), illustrated the limits of interpreting these comparisons (Douglas et. al, 1997). The comparison indicated that the difference between the RASS and rawinsonde (located some distance away) data are no larger than those between aircraft and rawinsonde data. Apparently, differences in measurement technique as well as differences in location contributed to the difference between the data. It is important to understand the limits these factors impose on interpreting this type of data comparison.

To prepare data comparison plans, Table 5 provides a list of collocated meteorological aloft resources during SCOS97-NARSTO. Please note that ozonesondes only provided temperature and relative humidity data. Please also note that when the sites are close but not exactly collocated, the comparison couples are in italics. At Hesperia, the relative humidity lidar may have temperature and wind data which can be compared to the profiler-RASS data. At the El Monte airport, this type of comparison is restricted to the study kick-off celebration day.

Table 3.4-1
SCOS97-NARSTO RWP-RASS NETWORK

ID	Name	Address	City	Site No.	(msl)	DD	MM	SS	DD	MM	SS	County	Air Basin
				AIRS	Elev	Latitude			Longitude				
EMAM	El Monte Airport-RWP-RASS		El Monte		91	34	4	12	118	2	0	Los Angeles	SoCAB
NAFB	Norton Air Force Base		Norton AFB		320	34	9	12	117	15	0	San Bernardino	SoCAB
ALPM	Alpine-Met		Alpine		463	32	51	53	116	48	27	San Diego	SDAB
BRWN	Brown Field		Brown Field Airport		160	32	34	20	116	58	46	San Diego	SDAB
CARL	Carlsbad		Carlsbad		110	33	8	22	117	16	0	San Diego	SDAB
CATM	Santa Catalina-Met-USC Research Station	USC Research Station Near Isthmus	Santa Catalina Island		37	33	26	44	118	28	56	Los Angeles	SoCAB
ECNT	El Centro		El Centro		-15	32	40	12	115	29	20	Imperial	SSAB
GOLE	Goleta		Goleta		3	34	25	46	119	50	47	Santa Barbara	SCCAB
HUEN	Port Hueneme		Oxnard		2	34	9	54	119	13	8	Ventura	SCCAB
LOSM	Los Alamitos		Los Alamitos		7	33	47	18	118	2	56	Orange	SoCAB
PALD	Palmdale		Palmdale		777	34	36	46	118	5	26	Los Angeles	SoCAB
SCLM	San Clemente Island-Met		San Clemente Island		53	33	1	7	118	35	7	San Diego	SDAB
TUST	Tustin		Tustin		16	33	42	25	117	50	15	Orange	SoCAB
USCZ	USC-Hancock Fnd Bldg	3616 Trousdale Parkway	Los Angeles		67	34	1	10	118	17	2	Los Angeles	SoCAB
VNUY	Van Nuys Airport		Van Nuys		241	34	12	57	118	29	31	Los Angeles	SoCAB
BARM	Barstow-Met	12 Guage Lake-10000 Ming Avenue	Barstow		694	34	55	23	117	18	25	San Bernardino	MDAB
HESO	Hesperia-Oak Hills Center	19709 Yanan Road	Apple Valley		975	34	23	29	117	24	17	San Bernardino	MDAB
RIHM	Riverside-H.J.Mills Water District	550 E. Alessandro Blvd.	Riverside		488	33	55	0	117	18	30	Riverside	SoCAB
THRM	Thermal Airport	56860 Higgins Drive	Thermal		-39	33	38	25	116	9	35	Riverside	SoCAB
TMCM	Temecula-East Municipal Water District	P.O. Box 8300	San Jacinto		335	33	30	0	117	9	40	Riverside	SoCAB
LAXP	Los Angeles Airport		Los Angeles		47	33	56	24	118	26	10	Los Angeles	SoCAB
ONTP	Ontario Airport		Ontario		290	34	3	22	117	36	11	San Bernardino	SoCAB
ESCM	Valley Center Met-Miller Pumping Station	Valley Center Muni Water Dist-Dermid Rd End	Valley Center		305	33	15	19	117	2	40	San Diego	SDAB
PTLP	Point Loma	End of Propogation-Building 599	Point Loma		30	32	41	48	117	15	15	San Diego	SDAB
VBG	Vandenberg Air Force Base		Vandenberg AFB		364	34	45	0	120	34	12	Santa Barbara	SCCAB
SVLM	Simi Valley Met - Madero Road Landfill"	End of Madero Road North	Simi Valley	61110008	366	34	17	27	118	47	52	Ventura	SCCAB

Table 3.4-2
SCOS97-NARSTO SODAR NETWORK

ID	Name	Address	City	Site No.	(msl)	DD	MM	SS	DD	MM	SS	County	Air Basin
				AIRS	Elev	Latitude			Longitude				
AZSM	Azusa-Met		Azusa		232	34	9	37	117	54	17	Los Angeles	SoCAB
CLAR	Santa Clarita Valley		Santa Clarita		450	34	25	27	118	31	37	Los Angeles	SoCAB
WSPM	Warner Springs - Met Site	Hwy 79-Puerta La Cruz Road-1 mile from hwy	Warner Springs		945	33	19	5	116	41	3	San Diego	SDAB
VBG	Vandenberg Air Force Base		Vandenberg AFB		364	34	45	0	120	34	12	Santa Barbara	SCCAB
29PA	29 Palms-Sand Hill-Turtle Site	29 Palms Marines Base-Air Ground Combat Center	29 Palms		764	34	18	40	116	15	10	San Bernardino	MDAB
29PB	29 Palms-Expeditionary Air Field (<8/20/97)	29 Palms Marines Base-Air Ground Combat Center	29 Palms		610	34	17	50	116	9	47	San Bernardino	MDAB
29PC	29 Palms-Expeditionary Air Field (>8/20/97)	29 Palms Marines Base-Air Ground Combat Center	29 Palms		619	34	17	53	116	10	15	San Bernardino	MDAB
LOSM	Los Alamitos		Los Alamitos		7	33	47	18	118	2	56	Orange	SoCAB

Table 3.4-3
SCOS97-NARSTO RAWINSONDE NETWORK

ID	Name	Address	City	Site No.	(msl)	DD	MM	SS	DD	MM	SS	County	Air Basin
				AIRS	Elev	Latitude			Longitude				
BAKM	Bakersfield-Met	1031 Mount Vernon Avenue	Bakersfield		99	35	20	44	118	57	59	Kern	SJVAB
RIRD	Riverside-CECERT-Facility	1200 Columbia Avenue	Riverside		285	34	0	0	117	20	9	Riverside	SoCAB
UCLA	UCLA-Met-Math Science Building	425 N. Hilgard Ave-Circle Drive-West of Franz Hall	Los Angeles		122	34	4	11	118	25	59	Los Angeles	SoCAB
NKX	Miramar National Weather Service Launch	Kearny Villa Rd North 1 mile Soledad Fwy right gate	Miramar		137	32	52	43	117	7	25	San Diego	SDAB
POMA	Pomona-security concern-last IOP no PM launch	924 North Gary Avenue	Pomona	60371701	274	34	4	2	117	45	7	Los Angeles	SoCAB
EDWD	Edwards AFB		Edwards		723	34	54	0	117	54	0	Kern	MDAB
VBG	Vandenberg Air Force Base		Vandenberg AFB		364	34	45	0	120	34	12	Santa Barbara	SCCAB
29PD	29 Palms-Expeditionary Air Field	29 Palms Marines Base-Air Ground Combat Center	29 Palms		611	34	10	48	116	5	24	San Bernardino	MDAB
TUSR	Tustin MCAS		Tustin		17	33	42	0	117	50	0	Orange	SoCAB
CHLK	China Lake Naval Air Warfare Center	Armitage Field	China Lake		665	35	45	0	117	40	48	Kern	MDAB
NVAS	Naval Air Station-North Island	Halsey Field	San Diego		0	32	20	24	117	4	12	San Diego	SDAB
PMGU	Point Mugu Naval Air Station	Building 552	Oxnard		3	34	7	16	119	7	20	Ventura	SCCAB
SNIC	San Nicolas Island NE Bldg 279	Coastal Road to Building 279	San Nicolas Island		14	33	16	47	119	31	11	Ventura	SCCAB

Table 3.4-4
SCOS97-NARSTO OZONESONDE NETWORK

ID	Name	Address	City	Site No.	(msl)	DD	MM	SS	DD	MM	SS	County	Air Basin
				AIRS	Elev	Latitude			Longitude				
CSUN	Cal State Northridge	18111 Nordhoff Street-Building	Northridge		267	34	14	13	118	31	47	Los Angeles	SoCAB
USCZ	USC-Hancock Fnd Bldg	3616 Trousdale Parkway	Los Angeles		67	34	1	10	118	17	2	Los Angeles	SoCAB
VCNO	Valley Center-CE-CERT Ozone Sonde	29216 Valley Center	Valley Center		366	33	13	57	117	1	28	San Diego	SDAB
ANAH	Anaheim	1610 South Harbor Boulevard	Anaheim	60590001	45	34	6	0.9	117	29	31.5	Orange	SoCAB
POMA	Pomona-security concern-last IOP no night launch	924 North Gary Avenue	Pomona	60371701	274	34	4	2	117	45	7	Los Angeles	SoCAB
ULDS	Upland - moved after training	1350 San Bernardino Aven Sp 62	Upland	60711003	379	34	5	52	117	39	0	Riverside	SoCAB
ESCO	Valley Center (Escondido)	600 East Valley Parkway-	Escondido	60731002	204	33	12	57	117	7	43	San Diego	SDAB
PMGU	Point Mugu Naval Air Station	Building 552	Oxnard		3	34	7	16	119	7	20	Ventura	SCCAB

Table 3.4-5

SCOS97-NARSTO COLLOCATED METEOROLOGICAL RESOURCES ALOFT

Data Source		Data Comparison	Site Information		
Agency	Contact	Couple	Site Description	Site ID	Platform
CE-CERT	Kurt Bumiller	1	(Upland to) Pomona	ULDS to POMA	rawinsonde-ozonesonde
U.S. Marines	N. Helgeson	2	29-Palms Exped. Air Field	29PA	SODAR
U.S. Marines	N. Helgeson	2	29-Palms Sand Hills	29PB & 29PC	SODAR-rawinsondes
NOAA	Bill Neff	3	Central Los Angeles - USC	USCZ	RWP/RASS
CE-CERT	Kurt Bumiller	3	Univ. of So. Calif.	USCZ	ozonesonde
ARB-MLD	Reggie Smith	4	El Monte Airport	EMAP	RWP/RASS
CE-CERT	Kurt Bumiller	4	El Monte Airport	EMAP	rawinsonde for kick-off
SDCAPCD	Jean Timmerman	5	Escondido-ValleyCtr	ESCM	RWP/RASS
CE-CERT	Kurt Bumiller	5	Escondido-ValleyCtr	VCNO	ozonesonde
U.S. Navy	Roger Helvey	6	Point Mugu	PMGU	rawinsonde-ozoneson
Radian	George Frederick	7	Riverside-HJMills W.D.	RIHM	RWP/RASS
CE-CERT	Kurt Bumiller	7	Riverside-CE-CERT Facility	RIRD	rawinsonde
NOAA	Bill Neff	8	Tustin	TUST	RWP/RASS
U.S. Navy	Roger Helvey	8	Tustin	TUSR	rawinsonde
U.S. Air Force	Chris Crosiar	9	Vandenburg AFB	VBG	RWP/RASS-SODAR
U.S. Air Force	Chris Crosiar	9	Vandenburg AFB	VBG	rawinsonde
NOAA	*Bill Neff*	*10*	*Van Nuys Airport*	*VNUY*	*RWP/RASS*
CE-CERT	*Kurt Bumiller*	*10*	*CSU Northridge*	*CSUN*	*ozonesonde*
NOAA	*Bill Neff*	*11*	*San Clemente Island*	*SCLM*	*RWP/RASS*
NOAA	*Roger Helvey*	*11*	*San Nicolas Island*	*SNIC*	*rawinsonde*
NOAA	*Bill Neff*	*11*	*Santa Catalina Island*	*CATM*	*RWP/RASS*
U.S. Navy	*Roger Helvey*	*11*	*Weather Afloat*		*rawinsondes*
Radian	*George Frederick*	*12*	*Hesperia-Oak Hills Water*	*HESO*	*RWP/RASS*
Penn State	*Philbrick, C. R.*	*12*	*Hesperia-Oak Hills Water*	*HESL*	*Relative Humidity Lidar*

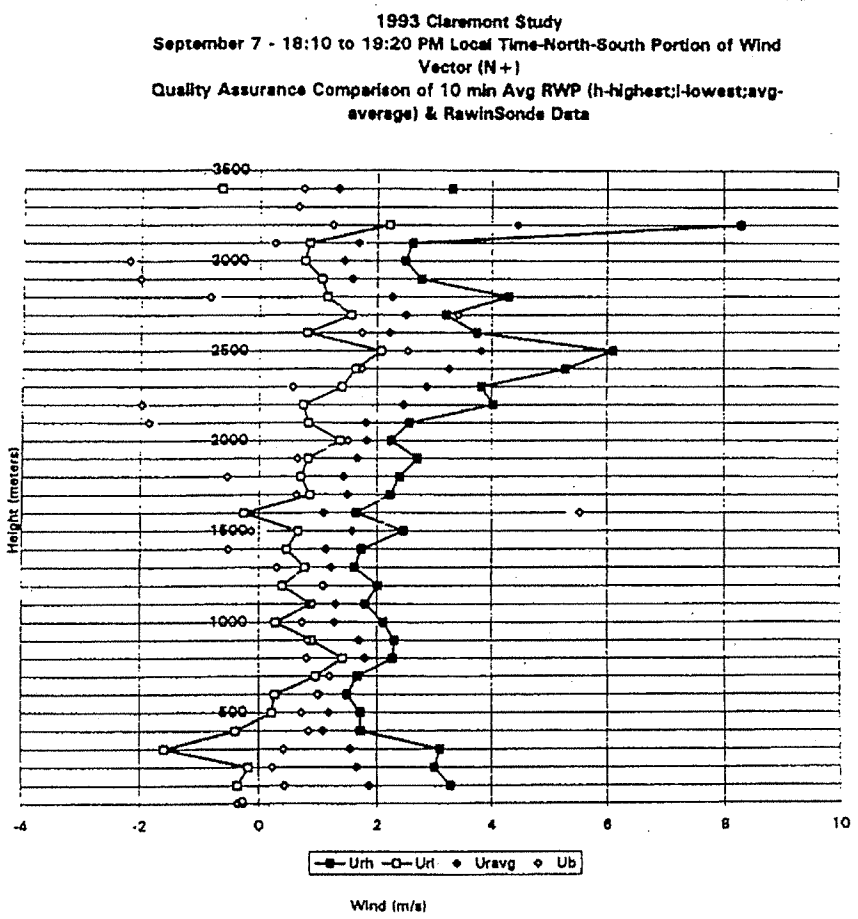
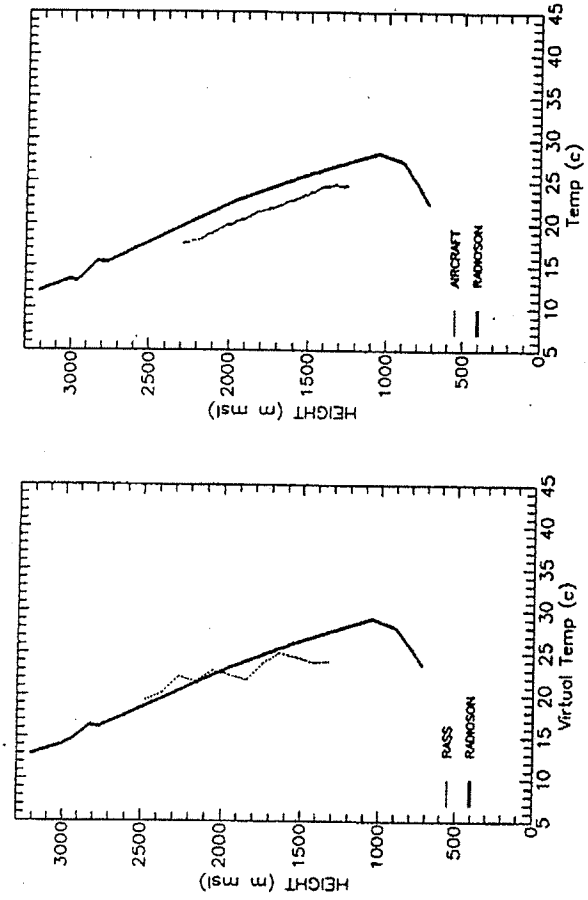


FIGURE 1-2b. Same as Figure 2-2a, but for the period 1810 to 1920 local time, 7 September.



AIRCRAFT: HES, 400 PST 1AUG92
RADIOSONDE: EDW, 200 PST 1AUG92

RASS: HES, 300 PST 1AUG92
RADIOSONDE: EDW, 200 PST 1AUG92

FIGURE 1-10a. Comparison of RASS and radiosonde derived virtual temperature for 1 August for HES (0300 PST) and EDWR (0200 PST) (left); comparison of aircraft and radiosonde derived temperature for 1 August for HES (0400 PST) and EDWR (0200 PST).

3.5 Air Quality Measurements Aloft

Characteristically, air pollution monitoring sites are located 3 - 10 meters above ground level in urban areas where the health impacts of air pollution are of greatest concern. However, to understand the formation and distribution of ozone on a regional scale, additional monitoring is needed in areas where the recirculation and transport of ozone and ozone chemical precursors may occur. This is especially important aloft, where the formation and distribution of ozone concentrations measured during previous studies in southern California are understood inadequately.

To better understand the vertical distribution of ozone on a regional scale, the SCOS97-NARSTO provided for an expanded network for air quality measurements aloft. These measurements aloft were made using six instrumented aircraft, seven ozonesonde release sites, and two ground-based lidars. The design of this network and the expected uses of these data are described below.

Data on air quality aloft were obtained during SCOS97-NARSTO by means of ozonesonde releases at seven sites, six aircraft, and two lidars. In addition, some supplemental surface monitoring sites were located on isolated peaks and a tall building to provide additional information related to air quality conditions aloft. These additional measurements provide critical detailed information pertinent to running and validating air quality models because the models can have difficulty simulating the observed vertical distributions of pollutants.

Because previous modeling efforts underestimated the amount of ozone in the central basin where ozone concentrations tend to be highest, the El Monte Airport, near the center of the basin, was established as the hub site for enhanced monitoring of conditions aloft. A 915-MHZ radar wind profiling system (RWP), operating throughout the June 16 through October 15 study period, and an ozone lidar, operating nearly continuously during the intensive periods, recorded data on the dynamics of ozone and meteorological conditions with height and time. Primarily on IOP days, these data were supplemented by measurements of ozone, oxides of nitrogen, temperature, humidity, and particles on up to nine aircraft spirals during daylight hours.

Previous studies demonstrated the complexity of air circulation offshore southern California and the importance of adequately characterizing the meteorological and air quality conditions there (e.g., Main *et al.*, 1990; Main *et al.*, 1991; Lehrman *et al.*, 1997). Air quality and meteorological monitoring offshore were greatly enhanced for the SCOS97-NARSTO; measurements were made aloft at several of these locations. During the IOPs, an instrumented aircraft (typically making morning and afternoon flights) provided additional, detailed data on conditions in the Southern California Bight during over-water sampling in an elliptical path encompassing the islands. On occasion, a second aircraft mapped the distribution of ozone concentrations inside the northeast quarter of the ellipse by sampling over the ocean west and southwest of Santa Monica Bay.

Lidar

Past air quality modeling applications have tended to underestimate ozone concentrations in the central portion of the air basin (typically, the region where ozone concentrations are highest). The primary objective of the ozone lidar in El Monte was to provide a continuous record of the development of ozone concentrations in this area. The lidar was located at the El

Monte Airport (see Figure 1). Ozone concentrations were monitored at ground level with a traditional ozone monitor and up to three kilometers with the differential absorption lidar (DIAL) using 266 nm as the on-line wavelength and 289 nm as the off-line wavelength. This lidar (Zhao *et al.*, 1994) has a larger range than other lidars because the laser energy is allocated among multiple parallel beams. The lidar's range resolution decreases from about 75 m at the bottom of the profile (150 m) to about 250 m near the top of the profile. The lidar also has a two-dimensional scanning capability in a vertical plane (NW to SE, perpendicular to the typical airflow in the region). These lidar data will be useful for 1) better understanding the dynamics of ozone formation in this area, 2) validating the performance aloft of modeling exercises, and 3) better quantifying ozone fluxes in the San Gabriel Valley.

Under the California Clean Air Act (Health and Safety Code, Section 39610) the transport of ozone (and ozone precursors) from one air basin to another is to be considered when evaluating the emission controls that might be necessary to bring an area into compliance with the California ambient air quality standard for ozone (1-hour average not to exceed 9 pphm). The upwind and receptor regions must control their emissions in a manner commensurate with their contribution to the ozone problem. With ozone concentrations in the SoCAB frequently violating the state and national ambient air quality standards and air typically flowing out of the SoCAB into neighboring air basins, quantification of ozone transport is a major concern. One of the major routes for airflow into the Mojave Desert is through Cajon Pass.

A lidar based on Raman shifts was positioned north of the Cajon Pass (see Figure 1) for a month beginning in late August. This lidar (Philbrick *et al.*, 1996) can measure water vapor, temperature, and aerosol scatter in addition to ozone. The temporal resolution of the water vapor and optical extinction profiles is about one minute while the temporal resolution for the ozone and temperature profiles is about half an hour. The water vapor data are obtained from the vibrational Raman scatter at 532 and 266 nm. The temperature data are obtained from the rotational Raman profiles of molecular nitrogen and oxygen. The optical extinction data are obtained from the gradients in the molecular nitrogen vibrational Raman profile. The ozone profiles are obtained from a DIAL analysis of the Raman shifted scatter of molecular nitrogen (285 nm) and molecular oxygen (276 nm). This lidar, because of its meteorological and ozone applications, will prove useful in understanding the meteorological dynamics influencing ozone transport.

Ozonesondes

Seven sites for releasing ozonesondes were established for the field study (see Figure 1). In principle, these sites collected data (by the potassium iodide method) on the vertical distribution of oxidant concentrations on a perimeter around the hub site at El Monte AP where the lidar provided nearly continuous ozone measurements during IOPs. Ozonesondes were released four times per day during IOPs. The release times were nominally 0200, 0800, 1400, and 2000 Pacific Daylight Time. The release times were offset from the rawinsonde releases (at 13 sites) by three hours to minimize the chances of signal interferences. In addition, the transmission frequencies of the ozonesondes (and their receivers) were modified in increments of 2 MHZ (between 400 and 406 MHZ) to reduce the possibility of a receiver locking onto the signal of another sonde if one were to drift into the vicinity of the receiver. The ozonesonde release sites were Pt. Mugu in Ventura County, California State University - Northridge (San Fernando Valley) and the University of Southern California in Los Angeles County, Anaheim in

Orange County, Pomona near the county line between Los Angeles and San Bernardino, the University of California-Riverside in Riverside County, and Valley Center in San Diego County.

Aircraft

Instrumented aircraft provided additional, detailed data on conditions aloft in the study domain, during IOPs and on some occasions the day before or after an IOP. Four aircraft were dedicated to the study and flew during the IOPs. Another aircraft, dedicated to mapping the distribution of ozone off the coast from Santa Monica Bay, was available to participate on about half of the IOPs. The sixth aircraft was dedicated to the aerosol component of SCOS97-NARSTO and flew on many days between late August and late September to characterize the 3-dimensional distribution of aerosols. This aircraft was equipped with an ozone analyzer and provided additional information on the relationships between particles and ozone. In general, each plane made morning and afternoon flights. Downward spirals were generally flown for characterizing the vertical distribution of pollutants. VOC and carbonyl samples were collected in altitude ranges not likely to include different air masses. Typical flight paths are portrayed in Figures 2 through 4.

The aircraft flights provided critical measurements of conditions aloft where carryover and transport of polluted air masses could significantly influence the performance of the model and influence pollutant concentrations at ground level. It is important that the air quality model application accurately simulate the ground level observations for the correct reasons. The over water flights are particularly critical to the success of the future modeling exercises because the upwind boundary conditions (i.e., the air quality flowing into the modeling domain). Ideally, the air quality should be "clean" of anthropogenic influences at the upwind boundary of the modeling domain. In southern California, the upwind boundary is generally the western boundary. Various measurement and modeling studies (e.g., Main *et al.*, 1990; Main *et al.*, 1991; Lehrman *et al.*, 1997; Edinger, 1973; Smith *et al.*, 1976; Johnson *et al.*, 1980; McElroy *et al.*, 1993; Lu *et al.*, 1996) have indicated that air circulations over southern California and the Southern California Bight are complex and that evidence of anthropogenic activity can routinely be found far offshore of the South Coast Air Basin.

Characterization of the air quality offshore is limited by cost, aircraft capabilities, safety, and even national security. The Southern California Bight includes test and exercise ranges for the U.S. military; when active, these military areas are off-limit to flight operations.

The primary objective of the Navajo was to make the ozone, NO_Y, and VOC measurements on the western boundary of the modeling domain and offshore. This aircraft was based out of Montgomery Field in San Diego County. The 4^+-hour flight would take generally take a clockwise elliptical route around the islands (i.e., south of San Clemente Island, south and west of San Nicolas Island, west, north, and east of the Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands), and east of Santa Catalina Island) before returning to Montgomery Field (see Figure 2). Modifications to the flight plan were made during the study to reduce the duration of the flight to ensure adequate fuel reserves and to avoid military airspace when training areas were "hot". Spirals were made near San Clemente Island, San Nicolas Island, Pt. Conception, and Santa Catalina Island. VOC samples were collected below 500 feet MSL near San Clemente Island, below 500 feet and between 4500 and 6000 feet near San Nicolas Island, between 4500 and 6000 feet near San Miguel Island, and below 500 feet near Santa Catalina Island.

The primary objective of the Aztec was to provide data on conditions in the northern portion of the study domain (see Figure 2). These data are particularly important for establishing the initial conditions but also for characterizing boundary conditions under scenarios such as the Type 5 Episode where the northern boundary becomes the upwind boundary for the study domain. Typically, the Aztec would fly the northern leg of its flight plan (i.e., through the Mojave Desert) in the morning of the first day of an IOP (to characterize initial conditions) and return to its base airport in Camarillo in the afternoon by flying through the SoCAB (to characterize the vertical structure of ozone and oxides of nitrogen during the build-up day of the ozone episode). On the remaining days of an IOP, the flight path was reversed with a flight through the SoCAB in the morning (to identify carryover from the previous day) and a flight through the Mojave Desert in the afternoon (to identify any afternoon transport). Spirals (generally over airports) to clearly characterize the vertical distribution of pollutants were made (depending on the flight path) at Camarillo and Simi Valley in Ventura County; Rosamond, Hesperia, and Yucca Valley in the Mojave Desert; Santa Monica Bay (near Malibu), VanNuys, and El Monte in Los Angeles County; Ontario and Rialto in San Bernardino County; and Banning and Riverside in Riverside County. The Aztec generally collected a total of eight VOC and carbonyl samples each day of an IOP. The Aztec also served as a back-up for the Navajo on the western boundary route.

The primary objective of the Cessna 182 operating in the SoCAB was to provide data on conditions in the central portion of the basin (see Figure 3). Two to three flights were flown per day from the base airport at El Monte to Burbank Airport to Cable Airport (near Fontana in San Bernardino County), to Fullerton Airport (in Orange County), and back to El Monte Airport with spirals being flown at each location. The two spirals per flight at the El Monte AP provided "calibration checks" on the performance of the ozone lidar located there. Two VOC and carbonyl samples were collected per flight: one at El Monte AP between 1600 and 2600 feet and one at Azusa, also between 1600 and 2600 feet.

The primary objective of the Cessna 182 operating in San Diego County was to provide data on conditions in the southern portion of the study area and to identify any overland transport of ozone into San Diego County from the SoCAB (see Figure 3). The typical flight plan for this aircraft took it from its base at Montgomery Field to Alpine to Valley Center to Temecula, to Pine Mountain Camp to Warner Springs to Lake Henshaw to offshore of Oceanside to offshore Encinitas to Lake Hodges to Gillespie Field to Montgomery Field. Spirals were performed at Alpine, Valley Center, Temecula, Pine Mountain Camp, and Oceanside. Four VOC and thee carbonyl samples were generally collected per flight.

The primary objective of the Partnavia was to map the 3-dimensional distribution of ozone concentrations and the horizontal extent of any ozone layers encountered off the coast of Ventura and Los Angeles Counties (see Figure 3). This aircraft was based at the Oxnard AP and was only available if other groups had not already reserved it. The flight route was primarily inside the northeast quarter of the ellipse defined around the islands by the flight path of the western boundary aircraft (i.e., the Partnavia mapped ozone concentrations over the ocean west and southwest of Santa Monica Bay).

The primary objective of the Pelican (a single-engine pusher type of aircraft) was to map the 3-dimensional distribution of aerosols in the SoCAB (see Figure 4). This aircraft was also based at the El Monte AP. The plane contained three different types of aerosol analyzers and

could generate detailed information on the size distributions of aerosols (between 0.005 and 47 microns). A secondary objective of the Pelican was to monitor ozone concentrations as it conducted its aerosol experiments.

Intercomparisons of air quality aloft measurements were made during SCOS97-NARSTO to evaluate the comparability of data from different platforms. The purpose of the intercomparisons was to identify and accurately quantify biases within (e.g., hysteresis in aircraft measurements) and between platforms. The University of California (Davis) aircraft served as a common link in the intercomparisons. The intercomparisons were scheduled so as not to interfere with activities during IOPs. Consequently, ozone concentrations during the intercomparisons generally were not as high as the sponsors desired.

3.6 Aerosol and Radiation Measurements

As discussed in section 2.3.2, ambient sampling was conducted at sites along two trajectories in the SoCAB (see Figure 3.6-1). To characterize the generation and evolution of urban aerosols, three sites [Los Angeles-North Main, Azusa, and the University of California at Riverside (UCR)] were selected along a trajectory from the emissions-rich central Los Angeles area, through the severely ozone-impacted San Gabriel Valley, and downwind to Riverside, the highest PM2.5 site in the SoCAB and perhaps the U.S. To characterize nitrate dynamics, measurements were made downwind of the most heavily populated portions of the Los Angeles coastal plain in Diamond Bar, immediately downwind of the ammonia-emitting dairy farms of the Chino Basin in Mira Loma, and further downwind in Riverside. To characterize the spatial and temporal variations in radiative quantities and photolytic rates attributable to scattering and absorption by aerosols, measurements were made at the surface in Riverside and above the mixed layer on Mt. Wilson (1725 m). The Riverside measurements were made at three sites on the University of California campus [Agricultural Operations (AgOps) monitoring station, College of Engineering-Center for Environmental Research and Technology (CE-CERT) rooftop, and Pierce Hall rooftop] within two miles of each other. The UCR sites were subject to approximately the same airmass, as verified with simultaneous ATOFMS measurements from June 29 to July 5, 1997.

Aircraft sampling over a wider area characterized vertical variations and the spatial extent of aerosol characteristics and irradiance observed along the trajectory. The flight paths are shown in Figures 3.6-1 and 3.6-2. To develop size distributions and composition profiles of fine particles emitted by gasoline- and diesel-fueled vehicles, measurements were made in the Caldecott Tunnel in northern California in November 1997. Table 3.6-1 lists all the participating measurement groups and Tables 3.6-2 through 3.6-4 contain a full listing of all the measurements collected.

Trajectory Study Measurements

Trajectory study collected continuous aerosol size distribution and composition data. simultaneously at three sites (see Table 3.6-2). U.C. Riverside measured real-time single particle size and chemical composition by Aerosol Time-of-Flight Mass Spectrometry (ATOFMS).

The new ATOFMS measurement technology permits sampling and experimentation (i.e., real-time measurement of the size and chemical composition of individual aerosol particles) that was previously prohibitively expensive or too time-consuming to be practical. ATOFMS can measure the aerodynamic size and chemical composition of up to 600 individual atmospheric particles per minute (50-100 under typical ambient conditions). These instruments permit direct observation of changes in ambient aerosols due to processes such as coagulation, condensation, evaporation, and heterogeneous gas/particle chemical reactions. Both the organic and inorganic content of individual aerosol particles can be determined. ATOFMS can be used to directly measure size and composition correlations for different particle sources, and to monitor particle transport and transformations. The ATOFMS measurements provide a wealth of data that will be used in development of source signatures for various PM sources, analysis of the temporal variation in aerosols at Riverside , and studies of aerosol chemistry in ambient air.

Aerosol Dynamics Inc. (ADI) conducted automated nitrate measurements at the Riverside Agricultural Station in August and at Mira Loma in September. Data were collected with 10 minutes time resolution over the entire measurement period. The analysis step took an additional minute, yielding 5 nitrate measurements per hour.

The ADI particle nitrate monitor provides automatic measurements using an integrated collection and vaporization cell. It has two modes of operation: sampling and analysis. In the sampling mode the sampled airstream passes through an impactor to remove particles above 2.5 μm, a denuder to remove interfering gaseous species and a humidifier to enhance particle collections. The particles in the airstream are then deposited by impaction onto a metal strip housed in the collection and vaporization cell. In the analysis mode the sample air flow is stopped. A carrier gas is introduced into the collection and vaporization cell and passes through the cell into the gas analyzer. The metal strip on which the particles have been deposited, located inside the cell, is rapidly heated by capacitor discharge. The heating process is less than a second. The deposited particles are vaporized and the evolved species are carried to a gas-phase analyzer for quantitation. By selection of the carrier gas and the amount of heating, a selected constituent of the deposited particles is converted to a gas-phase species that can be quantitated by a standard commercial analyzer. For automated nitrate analysis, particulate nitrate can be converted to nitrogen oxides, which can be analyzed by chemluminescence using a molybdenum converter. Ambient air is sampled at a flow rate of 1 liter per minute.

At each sampling site California Institute of Technology (Caltech) operated PM10 and fine particle filter samplers, two micro-orifice impactors (MOI), an electrical aerosol analyzer (EAA), an optical particle counter (OCP), and the data acquisition computer used for EAA and OPC. All sampling were in parallel with ATOFMS. The electrical analyzers were TSI (Minneapolis, MN) Model 3030 modified for increased sensitivity. The optical particle counter was Particle measuring Systems (Boulder, CO) Model ASASP-X 32 channel units.

Data from these electronic particle size monitors are currently being integrated for comparison with the mass distributions measured by impaction and the ATOFMS particle counting data. Real-time data from the OPCs and EAAs will be used to confirm the aerosol measurements of the MOI samples and the ATOFMS data. The filter-based samples were operated on the same 5-sample per day schedule (i.e., from 1 am to 6 am, 6:20 to 10 am, 10:20 am to 2 pm, 2:20 pm to 6 pm, and 6:20 pm to 1 am). The electronic samplers collected data continuously.

The filter samples are being analyzed to determine particle mass (PM10 and PM2.5), bulk composition (elemental carbon and organic carbon), and inorganic species concentrations (sulfates, nitrates, ammonium, chloride, and trace metals). In addition, denuder difference samples are undergoing analysis for nitric acid, and stacked filter samples for gas-phase ammonia. Two 48-hour average filter samples run in parallel collected enough particulate matter for quantification of trace organic species by gas chromatography/mass spectrometry (GC/MS). The fine particle samples are being analyzed for at least the approximately 50 organic compounds used for the source apportionment method developed at Caltech. The impactor samples are being analyzed to determine particle mass, bulk composition (elemental carbon and organic carbon), and inorganic species concentrations (sulfates, nitrates, ammonium, chloride, and trace metals) of the fine aerosol segregated into size fractions.

The College of Engineering-Center for Environmental Research and Technology (CE-CERT) at the University of California, Riverside, collected data on the concentrations of atmospheric nitrogenous species (NOy) which includes all species (e.g., nitrogen dioxide, peroxyacetyl nitrate [PAN], peroxypropyl nitrate [PPN], particulate nitrate, nitric acid, and nitrous acid).

At one site, Azusa, nitric acid and nitrogen dioxide were measured during ozone Intensive Operating Periods with a tunable diode laser absorption spectrometer (TDLAS). At Mira Loma ammonia was measured with a long-path Fourier transform infrared spectrometer (FT-IR) for two weeks, in early September. Denuder diffusion samples were also collected at these two sites over three hour intervals (from 10 am to 7 pm) to quantify nitric acid and ammonia. UC Riverside also collected PUF filters for PAHs and methylnitronapthalenes at all three sites for the first episode in August only. ARB collected 24-hour California Acid Deposition Program (CADMP) PM2.5 samples (mass and sulfate, nitrate, ammonium, chloride, sodium, potassium, calcium, and magnesium) at Los Angeles-North Main and Azusa for the two PM episodes in August.

Tunnel Study Measurements

The Caldecott Tunnel east of Oakland is uniquely configured with a center bore only open to passenger vehicles and side bores where trucks are shunted. Thus, the particulate matter concentrations in the center bore are dominated by light-duty gasoline vehicles, and the aerosol burden in the side bores are primarily due to emissions from heavy-duty diesel trucks. During the period November 17 through 21, four experiments were conducted with the ATOFMS and the Clatech's PM10 and fine particle filter samplers, two micro-orifice impactors, an electrical aerosol analyzer, an optical particle counter samplers (described above). To aid in data analysis and a carbon balance, the gas-phase precursors (i.e., CO, CO_2, speciated hydrocarbons, speciated carbonyl compounds, semi-volatile organic species) were sampled. An aerosol lidar was operated outside the tunnel. Data were also collected on fleet characteristics (e.g., count, speed, axles) to help in interpreting the results.

Fine Particle Measurement Study

The EPRI-sponsored Fine Particle Measurement Study was conducted at Riverside-AgOps from August 16 to September 22, 1997 (see Table 3.6-2 for a list of aerosol monitoring instruments). Both continuous and 24-hour-average samplers were deployed for the study, with duplicate side-by-side samplers installed when possible. Daily sample changes were made at 10:00 a.m. Pacific Daylight Time (PDT). The continuous aerosol nitrate monitor was operated at Riverside-AgOps during the first two weeks, after which time it was moved to the Mira Loma site. Other instruments were operated for the duration of the study.

Harvard University collected 24-hr samples by Harvard/EPA Annular Denuder System (HEADS), modified HEADS for inorganic ions, denuded filters for organic and elemental carbon, Harvard impactors for PM10 and PM2.5 mass, and FRM sampler for PM2.5 mass. Brigham Young University collected 24-hour samples for organics using their BOSS and BIG-BOSS systems, and for inorganic species using URG annular denuders and the R&P Chemspec automated denuder system. Real time instruments for particle mass included Harvard CAMMS, TEOM, and modified TEOM for PM2.5. Other real-time instruments were an aethelometer, ambient temperature nephelometer, ultraviolet wavelength particle absorption

spectrometer, and, for the first two weeks, the ADI automated nitrate system. The same measurements were be made each day, with sample changes at 0600 PDT.

Experiments

1. Measure total fine particle mass by a single filter-based method (similar in principle to the FRM). This was coordinated with EPA to obtain their FRM data for comparison (Harvard Impactor).
2. Measure air concentration of total fine particle mass in situ by a continuous method where the loss of labile substances is minimal (Continuous Ambient Mass Monitor System: CAMMS).
3. Measure air concentrations of major ions and elements in gaseous and particulate form (with emphasis on gaseous nitrate and ammonia) as well as the amount of these substances which evaporate from filters during sampling using denuder-based sampling methods (HEADS).
4. Measure air concentrations of fine particulate organic and elemental carbon (OC and EC) including the amount of particulate organic material that evaporates from the filters during sampling using denuder-based sampling methods (Brigham Young Organic Sampling Systems: PC BOSS/BIG BOSS).
5. Measure particulate nitrate concentrations continuously in the field using a research-grade continuous analyzer (Aerosol Dynamics, Inc. Automated Particle Nitrate Monitor).
6. Quantify the evaporation of labile and volatile species from filters as a function of storage time, temperature, relative humidity and other factors using laboratory generated submicron particles containing ammonium nitrate and specific volatile organic compounds (e.g., glutaric acid).

The difference between Items 1 and 2 will characterize the magnitude of the error due to the loss of labile substances and Items 3 and 4 will enable quantitative explanations for this error. To characterize the precision of the observations and to deal with unplanned glitches in the field, each observable was measured via redundant multiple samplers.

Item 5 provides higher time resolution nitrate data (continuous 5- to 10-minute averages) as compared to the 12-hour nitrate data in Item 3. Such data are valuable in relating air concentrations to fluctuating meteorology, especially in urban areas such as Los Angeles, where nitrate concentrations are high and their contribution to fine PM is large.

Item 6 will provide the most direct and definitive proof that specific compounds evaporate from filters during the course of sampling and before chemical analysis.

The team was led by Professor Petros Koutrakis of Harvard School of Public Health (HSPH) (Items 1, 2, 3 and 6). Other experimenters were Prof. Delbert Eatough of Brigham Young University (BYU) (Item 4) and Dr. Susanne Hering of Aerosol Dynamics, Inc. (ADI) (Item 5).

Dr. Pradeep Saxena of EPRI is the Principal Investigator for planning and synthesis across all aspects of the study and in that role will contribute to writing of the results in policy-relevant form.

Riverside-AgOps was one of several, approximately five-week-long field sampling campaigns conducted at urban locations throughout the country during 1996 to 1998 as part of the EPRI study. These "snap shot" measurements in Birmingham, Boston, Riverside, Chicago, Dallas, Phoenix, and Bakersfield were designed to give an indication of the geographical and seasonal variability of the PM2.5 mass and composition. Comparison of mass and chemical data from

continuous samplers (where loss of labile substances is believed minimal) with data from the more conventional filter-based methods (where losses may occur during or after sampling) will begin to characterize the magnitude of measurement error due to loss of labile substances. Another component of the study is evaluation of sampling methods in the laboratory, with tests aimed at understanding instrument precision, accuracy, and interferences or other limitations. The results of this multi-site/laboratory study will provide direct information on the magnitude of the loss of specific compounds and help guide the direction of future measurement research.

PM2.5 Federal Reference Method Nitrate Loss Measurements

The PM2.5 FRM Nitrate Loss Study was conducted in conjunction with the Trajectory Study. Two FRM samplers were operated side by side at each of the three Trajectory Study sites for the first four experiments.

In the December 1996 Federal Register, the Environmental Protection Agency states the design the design specifications for the proposed PM2.5 reference sampler. Prototype instruments have been constructed to these specifications by Graseby (Sumyrna, Georgia). These samplers contain a dichot inlet, a PM2.5 impactor with an oiled filter collection substrate, followed by a 47-mm Teflon filter. The FRM sampler is under positive flow control, i.e., using a small dry test meter to continuously monitor the flow volume, with a feed-back circuit to regulate the pumping speed. The sampler also has a fan to maintain the sampling chamber to within a few degrees of ambient temperature during sampling. All flow and temperature data are logged every five minutes during sampling period.

Daily sample changes were made at 1:00 a.m. PDT. At each site, one FRM unit collected particles on a Teflon filter and a second on a Teflon-nylon filter pack. Both types of filter packs were analyzed by ion chromatography. These results and those from collocated routine and research PM2.5 samplers will be used to quantify aerosol nitrate losses for the FRM.

Solar Radiation Measurements

The objectives of making radiation measurements, listed here in priority order, were to.

- Measure solar radiation and aerosol size, composition, and concentration and use the results to improve radiative transfer models suitable for calculation of spectrally resolved actinic flux.
- Compare diffuse and total irradiance observations from different types of broad band and spectrally resolved radiometers, and assess their utility for providing inputs for radiative transfer models or photochemical models.
- Provide observations if possible to help infer spatially resolved estimates of photolytic rates for an ozone episode of interest for the SCOS97-NARSTO domain.

The Radiation study built upon the extensive surface measurements of aerosol size, composition, and concentration detailed in Table 3.6-2 and the detailed characterization of aerosol size distributions aloft provided by the Pelican aircraft (described in the following section). With this foundation and in-kind services from several universities and agencies, relatively modest additional resources were required to collect a data set sufficient to examine interactions between aerosols and solar radiation.

Measurements of aerosols and of spectral and broad band irradiance were made, using identical or similar instruments, at two locations, the College of Engineering Center for Environmental Research and Technology (CE-CERT) in Riverside and at Mt. Wilson. Table 3.6-3 lists the instrumentation added specifically for the Radiation Study. Because Mt. Wilson was generally above the polluted mixed layer, the two sites provided contrasts in PM2.5, ozone, and trace gas concentrations and in the direct and diffuse solar radiation. Vertical profiles and horizontal distribution of aerosol size and concentration and of solar radiation were also provided by flights of the CIRPAS (Pelican) aircraft, described in the following section. Results from several key instruments listed in Table 3.6-3 will also be used to analyze the radiation results.

Temporal variation of the aerosol burden was observed by TEOM and ATOFMS at Riverside AO site, and by nephelometer and aetholometer at Riverside CE-CERT. Filter-based PM2.5 measurements were also made in Riverside. Video cameras recorded sky conditions at CE-CERT and Mt. Wilson.

Spectral irradiance was continuously observed at both sites using two different instruments, Brewer spectral radiometers operated at both sites by the University of Georgia and CE-CERT, and the Yankee ultraviolet multi-filter rotating shadowband radiometer (UVMFR), operated by the National Renewable Energy Laboratory from Colorado State University.

Broadband (total and diffuse) irradiance was continuously observed by CE-CERT at each site using pairs of duplicate radiometers (Eppley UV, Eppley PSP, and Eppley 8-48), operated both with and without shadowbands. These radiometers were chosen to match radiometers in widespread use in existing networks throughout southern California. For quality assurance purposes these radiometers were intercompared at Riverside prior to installation at Mt. Wilson. Radiometers from this group were also compared with the radiometers on the STI Aztec and the CIRPAS Pelican.

"Radiation intensive" days were selected for cloud free conditions, to coincide with episodes of ozone or PM, or to take advantage of special aircraft- and ground-based observations of aerosol size distributions and chemistry. These days included periods of light and heavy aerosol burden. On these days, CE-CERT operated an NO_2 actinometer to measure the photolytic rate for NO_2 and a LI-COR 1800 spectral radiometer with intermittent manual shading to measure spectrally resolved total and diffuse irradiance.

Intensives on August 27-28, September 4-6, 10, 12 were supported by the CIRPAS aircraft. By making spirals near CE-CERT and Mt. Wilson, the aircraft provided vertical profiles of irradiance and aerosol size and concentration for testing and improvement of models of radiative transfer. Intensive radiation measurements were also made on August 21-23 and October 30-November 1, but without the CIRPAS aircraft. An additional aircraft which flew during ozone IOPs did not measure aerosols, but did measure solar irradiance (Eppley PSP).

Aerosol Aircraft Measurements

For aerosol and radiation measurements aloft (see Table 3.6-4), the Pelican aircraft was operated by the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS), a consortium of the Office of Naval Research, the Naval Postgraduate School, the California Institute of Technology, and Princeton University. Between August 27 and September 13, CIRPAS obtained

measurements of the concentrations and size distributions of particulate matter and its constituent chemical species. The Pelican is a modified Cessna 337 Skymaster that has been reconfigured as a single engine pusher to allow sampling of unperturbed air from the front of the aircraft. With a standard payload of 330 lbs (150 kg) in an unobstructed nose cone, the Pelican can currently be operated in conventional on-board pilot mode. Wing hard points have been added to provide mounting pads for externally mounted payload pods or probes. Missions of approximately eight hours can be flown with on-board pilots flying over high population areas. During missions, real-time ground station access to scientific data and flight information from the Pelican is available via satellite data link. The airplane has a 43 ft wingspan and is 37 ft in length. The aircraft was housed at El Monte Airport in a hanger leased by Caltech.

The Pelican was designed to have the following capabilities:

- Optional piloting, i.e., conventional or as a remotely piloted aircraft (RPA)
- Endurance of up to 24 hours of RPA operations and 8 hours for onboard-piloted missions
- Range of 2500 km
- Mission altitude ranging from 20-4000 m
- Loiter speed as low as 40 m/s
- kg payload for 24-hour missions - 500 kg for 2-hour missions
- Fuselage nose volume of 1 m^3
- Main cabin payload volume (for on-board piloted missions) of 0.33 m^3
- Standard wing mounts for interchangeable pylon-mounted payloads at 50 kg each
- Palletized instrument capability
- Payload power = 1 kW at 28 V
- Satellite interactive communications for over-the-horizon operations

Aerosol size distributions in the range from 0.005 to 10 μm diameter were measured by an array of three instruments (RCAD, PCAS-100XP, and FSSP-300) with approximately 1-minute time resolution. PM2.5 particles were sampled using three parallel sampling trains that provided PM2.5 mass, elemental carbon, organic carbon, sulfates, nitrates, ammonium, chloride, and trace elements. Filter sampling for aerosol composition was performed on a 1-hour sampling duration. For a typical 8-hour flight mission, this allowed for about 7 to 8 series of filter samples per mission. The aircraft was also instrumented to monitor SO_2 and broadband solar and uv irradiance.

Flight Plans: Due to differences in the time resolutions of continuous and filter-based measurements, the Pelican flew two types of paths with different sampling objectives. The primary flight path (Figure 3.6-1) was designed to observe the three-dimensional evolution of aerosol size and concentration along the same west-to-east path as the first set of Trajectory Study experiments. This flight path consisted of spirals and traverses, and was designed to make use of continuous size and concentration measurements. A secondary flight path (Figure 3.6-2) was chosen to investigate nitrate dynamics aloft along the Trajectory Study path from Diamond Bar through the ammonia source area in the Chino Valley dairy district and on to the nitrate-rich aerosol found at Riverside. This path included traverses and constant altitude orbits to match the 1-hour sampling time for filter-based sampling that provides information on aerosol composition.

For spiral and traverse flight paths, a typical flight took 4 hours. Two flights per day were performed, with the morning flight starting at about 06:00 Pacific Daylight Time (PDT) and the

afternoon flight starting at about 13:00 PDT. The spirals were made at locations where the Pelican aircraft could safely approach the ground, as close as possible to the intensive ground-level aerosol monitoring sites. Also, during intensive operational periods (IOPs) of SCOS97-NARSTO ozone program, the STI and UCD aircraft made measurements of VOC, NO, NO_X, NO_y, ozone, sulfur dioxide, particle light scattering, solar radiation, and meteorological parameters not only in the Pelican aircraft flight area, but broader area of southern California as well. Flight plans of multiple aircraft were conducted to have overlapping segments at least once per day to allow intercomparisons between the systems. For flights that occurred during IOPs for ozone episodes, the Pelican spiraled near the ozone lidar based at El Monte Airport at the start and end of the flight. The results will be used to intercompare the ozone and aerosol extinction measurements from both sampling platforms.

For 3-dimensional aerosol and radiation characterization (Figure 3.6-1), the Pelican took off from El Monte Airport to make an upward spiral then traverse to northern Santa Monica Bay where a downward spiral was made just offshore. Additional spirals were performed near Altadena, Azusa, Cable Airport, Rialto Airport, Riverside Municipal Airport, Chino Airport, Fullerton Airport, and Seal Beach. To document the horizontal gradients, traverses between spiral locations were at a constant altitude. The spiral near Altadena began near 1,000' above ground level and ascended to an altitude of about 7,000' -- well above the altitude of the Mt. Wilson observatory (5,791'). The upper levels of this spiral will be used to assess the aerosol load above the height of the solar radiation observations at Mt. Wilson. The lower levels of the Altadena spiral will allow a comparison with the observations from the spiral near Azusa. Additional ground-level radiation measurements were made at UC Riverside (CE-CERT) and at Mt. Wilson during August and September ozone and radiation IOP. Measurements were intended primarily to provide a data set suitable for evaluation of a radiative transfer model.

For the nitrate-oriented study (Figure 3.6-2), orbit flights were performed during a two-day episode of ground-level sampling (orbit is a circular or elliptical path flown at a constant altitude above a fixed point). Three sites -- Diamond Bar, Mira Loma, and UC Riverside -- were selected in the SoCAB to examine the formation of fine nitrate particles. The Mira Loma site was selected because there are large dairy farms just upwind (strong NH_3 source), and has a continuous air quality record since 1993 at the adjacent Jurupa Valley High School (Children's Health Study site).

The aircraft took off from El Monte Airport and made an upward spiral before traversing to Diamond Bar, Mira Loma, and UC Riverside. The Pelican aircraft flew repeatedly over the same path to provide sufficient sample time for collection of integrated samples for chemical analyses. A typical sampling duration was about one hour. The return traverse from Riverside to the El Monte Airport was from Riverside to Anaheim to offshore of Huntington Beach, then to Seal Beach, then inland northward back to the El Monte Airport, spiral down and land. The purpose of the indirect return path was to measure near surface aerosol concentrations over a greater area of the South Coast Air Basin, and especially to check transport along the Santa Ana river, which parallels the other major transport path between the Pacific ocean and Riverside . For the spiral, orbit, and traverse flight paths, a typical flight path took about 8 hours, allowing one flight per day.

Each of the six studies, discussed above, has a data analysis or modeling component. Many groups involved in the Aerosol Program, including EPRI, Harvard, BYU, SCAQMD, Caltech, and ADI, will be involved with comparisons among the various aerosol measurement methods.

Two of the more intensive efforts are for the Trajectory Study and the Radiation Study. The major objective of the Trajectory Study was to determine the relative contributions of sources such as gasoline engine exhaust, diesel exhaust, woodsmoke, food cooking aerosol, road dust, and secondary organic aerosol to PM2.5 concentrations in the SoCAB. To meet this objective, Professor Glen Cass of the California Institute of Technology will calculate source contributions to the fine organic aerosol concentrations and to overall primary fine particle mass concentrations at the three sampling sites for four of the two-day episodes. Source apportionment of fine organic aerosol and fine aerosol mass concentration will be achieved by applying a chemical mass balance model that relates source contributions to ambient PM2.5 concentrations using molecular markers. The chemical profiles of the emission sources were developed from the Tunnel Study and previous studies.

Efforts to evaluate and improve radiative transfer models suitable for simulating the effects of aerosols on photolytic rates will be led by Professors Robert Harley of the University of California at Berkeley and Nancy Brown of Lawrence Berkeley National Laboratory, and they will incorporate these results into existing photochemical models. In addition, the research instruments at CE-CERT and Mt. Wilson will be used to evaluate collocated broadband irradiance measurements to determine the utility of using existing networks of radiometers to aid in estimating semi-quantitatively the spatial and temporal trends and differences in photolytic rates across the SCOS97-NARSTO modeling domain.

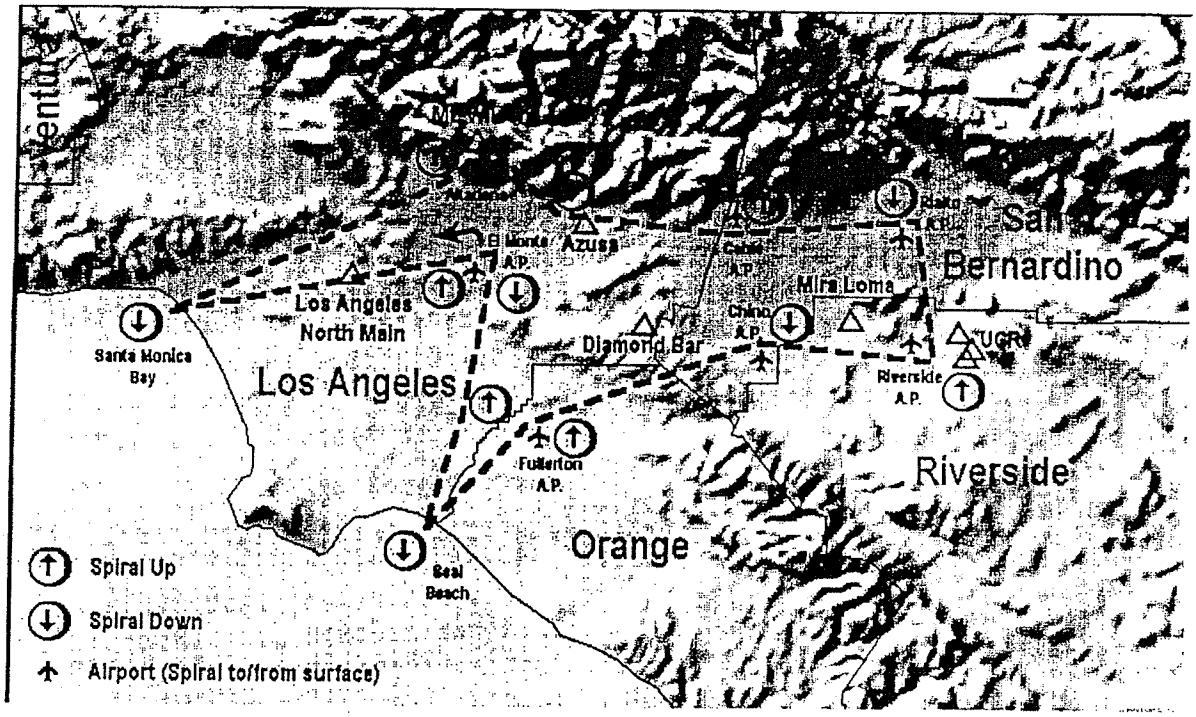


Figure 3.6-1. SCOS97-NARSTO Aerosol Program and Radiation Study surface sites with Pelican aircraft flight plan for 3-dimensional aerosol and radiation characterization.

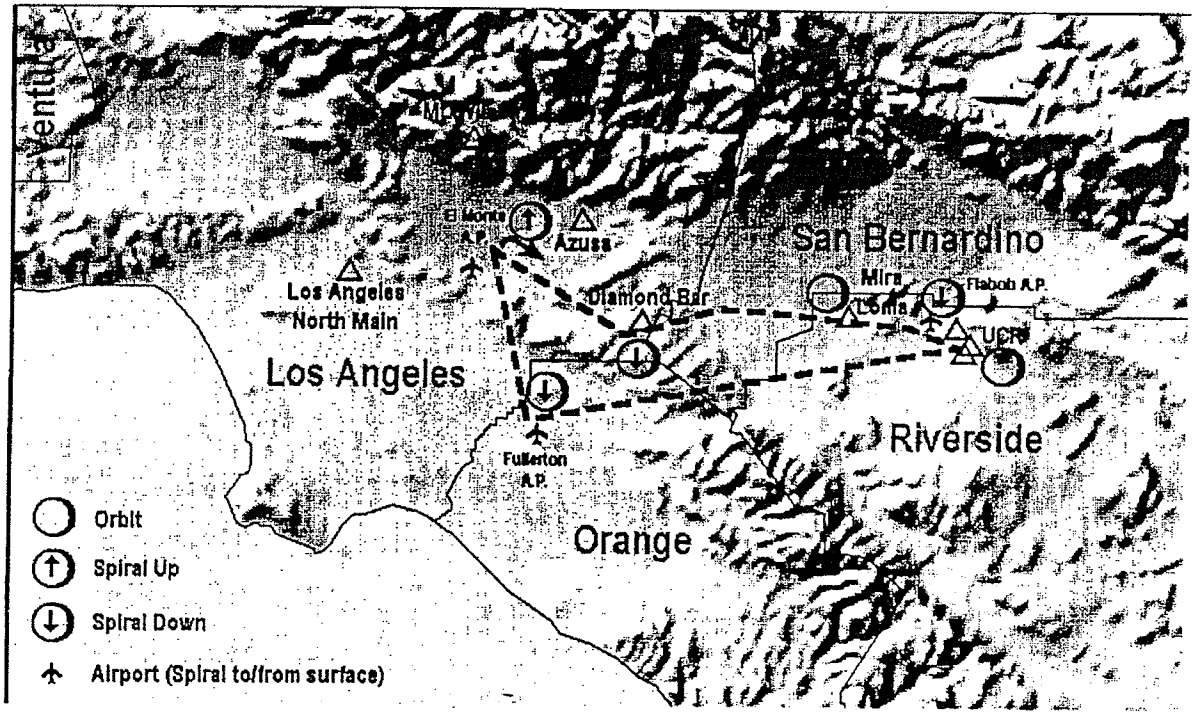


Figure 3.6-2. Pelican aircraft flight plan for nitrate aerosol characterization.

Table 3.6-1. SCOS97-NARSTO Aerosol Program and Radiation Study measurement groups.

Organization	Investigators
Aerosol Dynamics, Inc. (ADI)	Susanne Hering
Brigham Young University (BYU)	Delbert Eatough, Norman Eatough
California Air Resources Board (CARB)	Curtis Schreiber, Thelma Yoosephiance
California Institute of Technology (Caltech)	Glen Cass, Jonathan Allen, Lara Hughes, Philip Fine, Robert Johnson, Paul Mayo, Lynn Salmon
Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS)	John Seinfeld, Richard Flagan, Haflichi Johnson, Mark Frolli, Paul Finn, Kenneth Liao, Lynn Russell
Colorado State University - National Renewable Energy Laboratory (CSU-NREL)	James Gibson, George Janson, William Durham
Desert Research Institute (DRI)	Barbara Zielinska, Larry Sheetz
Harvard University School of Public Health (Harvard)	Petros Koutrakis, George Allen, Mark Davey
South Coast Air Quality Management District (SCAQMD)	Rudy Eden, Steve Barbosa, Solomon Teffera, Mel Zeldin
University of California at Davis (UCD)	Debbie Niemeier, Britt Holmen, Judi Charles
University of California at Riverside - Department of Chemistry (UCR)	Kimberly Prather, Markus Gaelli, Eric Gard, Deborah Gross, and the rest of the Prather Group
University of California at Riverside - College of Engineering-Center for Environmental Research and Technology (UCR CE-CERT)	William Carter, Dennis Fitz, Michael McClanahan
University of California at Riverside - Statewide Air Pollution Research Center (UCR SAPRC)	Ernesto Tuazon, Janet Arey, Roger Atkinson
University of Georgia	John Rives, Wanfeng Mou

Table 3.6-2. SCOS97-NARSTO Aerosol Program instrumentation.

Organization	Parameter	Instrument	Duration	Site
Trajectory, Tunnel, and PM2.5 FRM Nitrate Loss Studies (sponsored by CARB, CRC, and NREL)				
ADI	NO_3-	Automated nitrate monitor	continuous	ML
ADI	PM2.5 mass	FRM	24-hr (1 am start)	AZ, DB, LA, ML, PH
Caltech	PM2.5 organic species	Cyclone-filter sampler	5 samples/day	AZ, DB, LA, ML, PH, CD
Caltech	PM2.5 mass, EC, OC, $SO_4^=$, NO_3-, NH_4^+, HNO_3, trace elements	Cyclone-filter with denuder sampler	5 samples/day	AZ, DB, LA, ML, PH, CD
Caltech	PM10 mass, EC, OC, $SO_4^=$, NO_3-, NH_4^+, NH_3, HNO_3, trace elements	Cyclone-filter sampler	5 samples/day	AZ, DB, LA, ML, PH, CD
Caltech	Size-resolved aerosol (mass, $SO_4^=$, NO_3-, NH_4, trace elements)	Micro-orifice impactor	5 samples/day	AZ, DB, LA, ML, PH, CD
Caltech	Size-resolved aerosol (mass, EC, OC)	Micro-orifice impactor	5 samples/day	AZ, DB, LA, ML, PH, CD
Caltech	Particle size, number	Electrical aerosol analyzer	continuous	AZ, DB, LA, ML, PH, CD
Caltech	Particle size, number	Optical particle counter	continuous	AZ, DB, LA, ML, PH, CD
DRI	CO, CO_2, C_1-C_{12} hydrocarbons, MTBE, C_1-C_7 carbonyl compounds, PAH	Canister and cartridge samplers	3-hr	CD
UCD	C_1-C_7 carbonyl compounds	Cascade and cartridge samplers	3-hr	CD
UCR	Size & composition of single particles	Aerosol time-of-flight mass spectrometer	continuous	AZ, DB, LA, ML, PH, CD
UCR CE-CERT	NO_y, HNO_3	TECO 42CY	continuous	AO, AZ, DB, LA, ML
UCR CE-CERT	NH_3, HNO_3	Denuder diffusion	3-hr (10 am-7 pm)	AO, AZ, DB, LA, ML
UCR SAPRAC	NH_3, HNO_3	Long-path Fourier transform spectrometer	continuous	ML
UCR SAPRAC	PAH	XAD-2 resin filter sampler	continuous	ML
Fine Particle Measurement Study (sponsored by EPRI and SCE)				
ADI	NO_3-	Automated nitrate monitor	continuous	AO
BYU	PM2.5 mass	R&P FRM prototype	24-hr (10 am start)	AO
BYU	PM2.5 mass	TEOM sandwich prototype	continuous	AO
BYU	PM2.5 mass	TEOM with desiccation prototype	continuous	AO
BYU	PM2.5 mass, TC, $SO_4^=$, NO_3-	Multi-channel samplers (PC/BOSS, BIG BOSS)	24-hr (10 am start)	AO
BYU	$SO_4^=$, NO_3-, SO_2, HNO_3	Annular denuder/cyclone/filter sampler (Chem Spec)	24-hr (10 am start)	AO

Organization	Parameter	Instrument	Duration	Site
BYU	$SO_4^=$, NO_3-, SO_2, HNO_3	Annular denuder/filter sampler (URG)	24-hr (10 am start)	AO
Harvard	$SO_4^=$, NO_3-, NH_4^+, SO_2, NH_3, HNO_2, HNO_3, strong H^+	Annular denuder sampler (HEADS)	24-hr (10 am start)	AO
Harvard	PM2.5 and PM10 mass	Harvard impactor	24-hr (10 am start)	AO
Harvard	PM2.5 mass	CAMMS - filter pressure drop prototype	continuous	AO
Harvard	EC, OC	Carbon sampler, with and without gas phase stripper	24-hr (10 am start)	AO
Harvard	Light-absorbing aerosols	BC aethelometer	continuous	AO
Harvard	Light-absorbing aerosols	UV aethelometer	continuous	AO
Harvard	Light-scattering aerosols	Nephelometer	continuous	AO
Routine Monitoring Measurements				
CARB	PM2.5 mass , $SO_4^=$, NO_3-, Cl-, NH_4^+, Na^+, K^+, Ca^{+2}, Mg^{+2}	CADMP sampler	24-hr (6th day)	LA, AZ
SCAQMD	PM10 mass	TEOM	continuous	LA, AO, ML
SCAQMD	PM10 mass	BAM	continuous	LA
SCAQMD	O_3, NO_x, CO	Standard analyzers	continuous	AO, ML
SCAQMD	PM2.5 mass, $SO_4^=$, NO_3-, Cl-, NH_4^+, HNO_3, HCL, HCOOH, CH_3COOH	Two-week integrated sampler	two-week	AO, ML
SCAQMD	Light -scattering aerosols	Nephelometer	continuous	LA, AZ
SCAQMD	Light-absorbing aerosols	AISI tape sampler	continuous	LA, AZ
SCAQMD	PM10 mass, $SO_4^=$, NO_3-, Cl-	Hi-Vol SSI sampler	24-hr (6th day)	LA
SCAQMD	PM2.5 & PM10 mass and elemental species	Dichotomous sampler	24-hr (6th day)	LA
SCAQMD	PM10 and PM2.5 mass, EC, OC, $SO_4^=$, NO_3-, Cl-, NH_4^+, K^+, HNO3, trace elements	PTEP sampler	24-hr (6th day)	DB
SCAQMD	TSP mass , $SO_4^=$, NO_3-	Hi-Vol sampler	24-hr (6th day)	LA, AZ

Sites
AO = UC Riverside - Agricultural Operations
AZ = Azusa
CD = Caldecott Tunnel
DB = Diamond Bar
LA = Los Angeles - North Main
ML = Mira Loma
PH = UC Riverside - Pierce Hall

Other
BAM = Beta Attenuation Monitor
CADMP = California Acid Deposition Monitoring Program
FRM = Federal Reference Method
Hi-Vol SSI = High Volume Size-Selective Inlet
PTEP = PM10 Technical Enhancement Program
TEOM = Tapered Element Oscillating Monitor

Table 3.6-3. Instrumentation at Mt. Wilson and Riverside for the SCOS97-NARSTO Radiation Study.

Mt. Wilson [1]	Riverside CE-CERT	Parameter	Instrument	Spectral Resolution; Range (nm)	Operator
Spectral Radiometers and Actinometer					
√	√	Spectral UV irradiance (and column O_3, NO_2, SO_2)	Brewer Spectral Radiometer	0.5nm; 286.5 - 363	CE-CERT/ U. Georgia
√	√	Total, direct, & diffuse spectral UV irradiance	Yankee UVMFR, multi-filter rotating shadow band	2nm; 300, 305.5, 311.5, 317.5, 325, 332.5, 368	CSU-NREL
√	√2	Total & diffuse spectral irradiance	LI-COR 1800 (& hand shading)	2nm; 300 - 1100	CE-CERT
√	√2	Rate of NO_2 photolysis	NO_2 Actinometer	broadband; 290-420	CE-CERT
Broadband Radiometers					
√	√	Total & diffuse UV irradiance	Eppley UV (& shadow band) [3]	broadband; 295-385	CE-CERT
√	√	Total & diffuse irradiance	Eppley PSP (& shadow band) [3]	broadband; 285-2800	CE-CERT
√	√	Total & diffuse irradiance	Eppley 8-48 (& shadow band) [3]	broadband; 285-2800	CE-CERT
Aerosol Measurements and Cameras					
√4	√5	Single particle size, composition	ATOFMS	N/A	UCR
√	√	Light-scattering aerosols	Nephelometer, Optec NGN-2	visible	CE-CERT
√	√	Light-scattering aerosols	Nephelometer, MRI 1590	visible	CE-CERT
√	√	Light-absorbing aerosols	AISI Tape Sampler (COH)	visible	CE-CERT
√	√	Light-absorbing aerosols	Aethelometer	visible	CE-CERT
√6	√	Visible sky conditions	Video Camera	visible	CE-CERT

[1] The original Mt. Wilson site was replaced and fully instrumented on August 21.

[2] Operated on June 29-July 5, August 21-23, 27-28, September 4-6, 10, 12, and October 30-November 1.

[3] Duplicate instruments, with and without shadowbands, operated at each site.

[4] Portable ATOFMS was operated at Mt. Wilson on initial radiation intensive days of June 29-July 5.

[5] Operated at UCR-Pierce Hall during all periods of intensive monitoring for radiation.

[6] Video camera operated by NOAA, looking southeast and downward on the mixed layer. Still camera operated by Portland State.

Table 3.6-4. Instrumentation on the CIRPAS Pelican.

Parameter	Instrument
Position	Trimble Navigation, TRNS Vector GPS
Altitude	Rockwell, radar altimeter
Aerosol size distributions, 0.005 to 0.15 μm, 45 channels, 1 min	Caltech, Radially Classified Aerosol Detector (RCAD), Differential Mobility Analyzer
Aerosol size distributions, 0.1 to 3.0 μm, 15 channels, 1 sec	Particle Measuring Systems, Passive Cavity Aerosol Spectrometer PCASP-100X
Cloud droplet size distributions, 0.5 to 47.0 μm, 15 channels, 1 sec	Particle Measuring Systems, Forward Scattering Spectrometer Probe, FSSP-100
Cloud droplet size distributions, 21 to 260 μm	Particle Measuring Systems, OAP-260X Spectrometer
Cloud droplet effective radius and liquid water content	PVM 100
Residual particles from evaporated cloud droplets ≤ 7 μm	Stockholm University, Counter-flow Virtual Impactor (CVI)
Light-scattering aerosols	TSI, multi-wavelength (450, 550, and 700 nm) integrating nephelometer
Dimethyl sulfide, carbonyl sulfide, and SO_2	RVM Scientific, automated gas chromatograph
Ozone	Dasibi, 1008-AH
One-hour integrated PM2.5 mass, EC, OC, $SO_4^=$, NO_3-, Cl-, NH_4^+, trace elements	Aerosol Dynamics, Inc., multichannel one-hour integrated PM2.5 sampler
Temperature (static)	Rosemont, 102
Pressure (static)	Rosemont, 1201
Pressure (dynamic)	Setra, 239
Dew Point	Edgetech, 137-C3 Hygrometer
Solar irradiance, downward and upward	Eppley PSP
UV irradiance, downward	Eppley UV

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